CARBON DIOXIDE, CLIMATE CHANGE CERTAINTIES, UNCERTAINTIES PUZZLES & PROSPECTS

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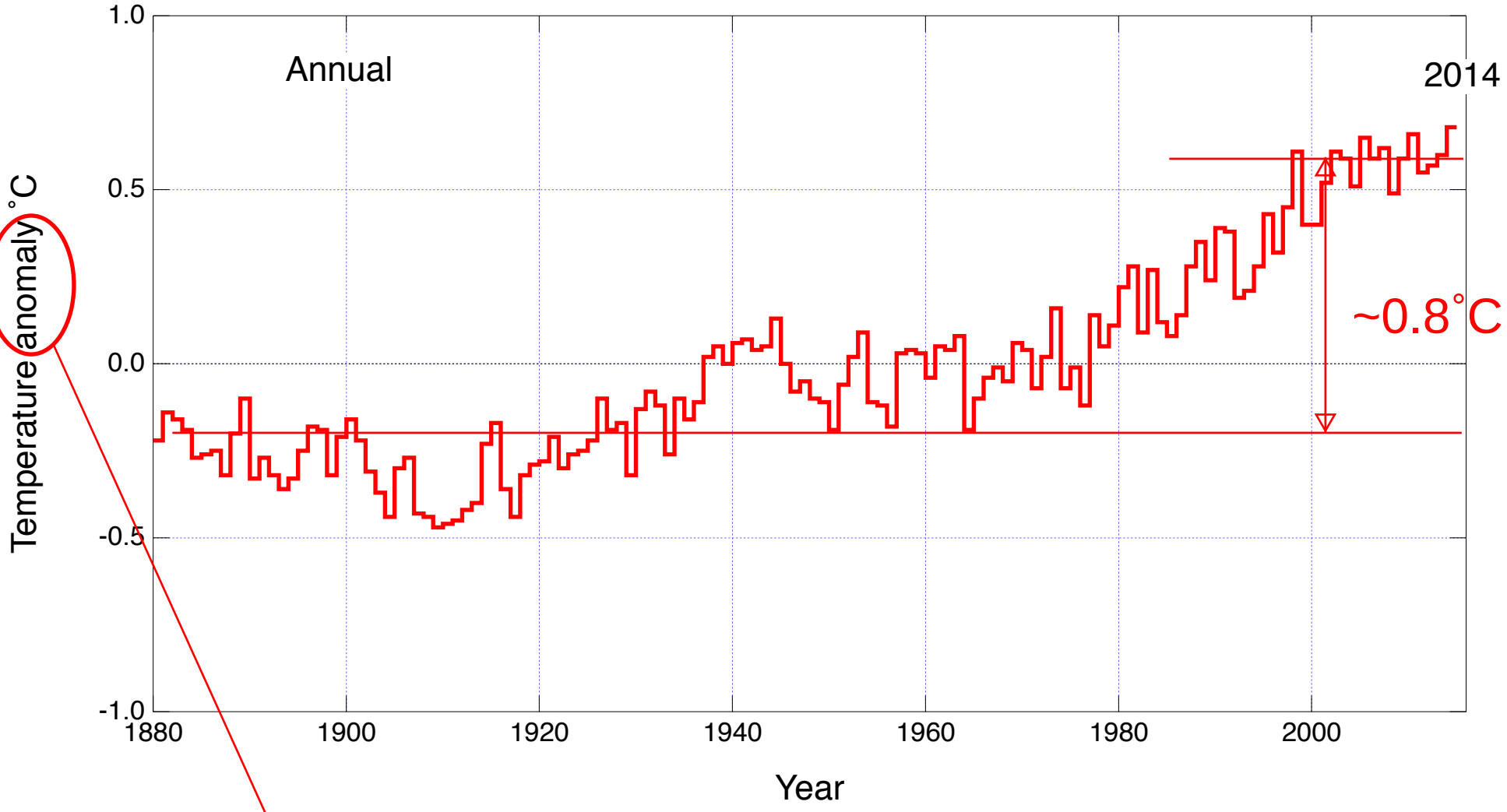
March 12, 2015

www.ecd.bnl.gov/steve

GLOBAL TEMPERATURE CHANGE SINCE 1880

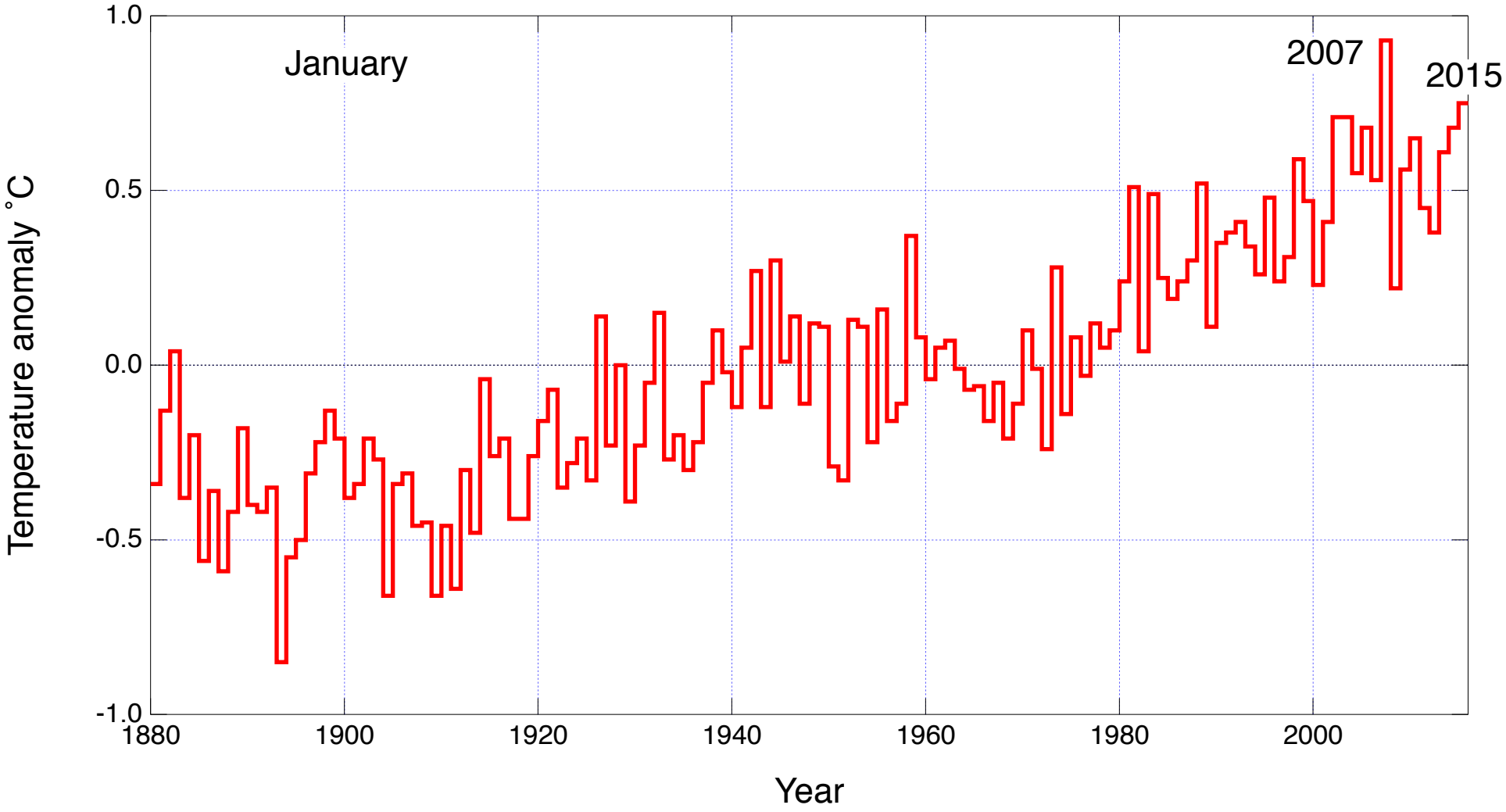


NASA, Goddard Institute for Space Studies

2014 was the hottest year on record. 14 of the hottest 15 years since 2000.

Anomaly: Departure from climatological average

GLOBAL TEMPERATURE CHANGE SINCE 1880

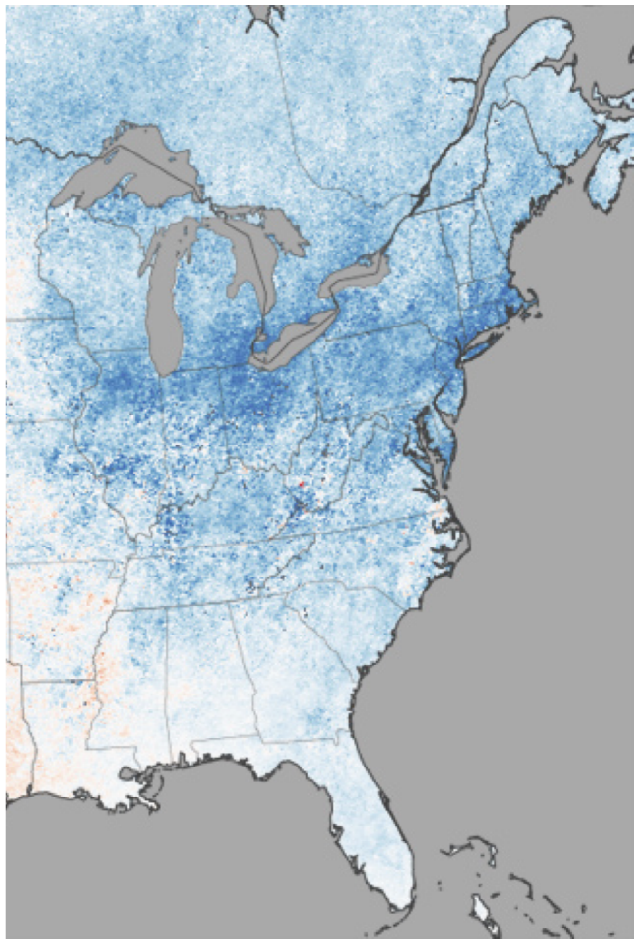


NASA, Goddard Institute for Space Studies

January 2015 was second hottest January on record (after 2007).

SATELLITE MEASURED TEMPERATURE ANOMALY

Eastern U.S., February, 2015

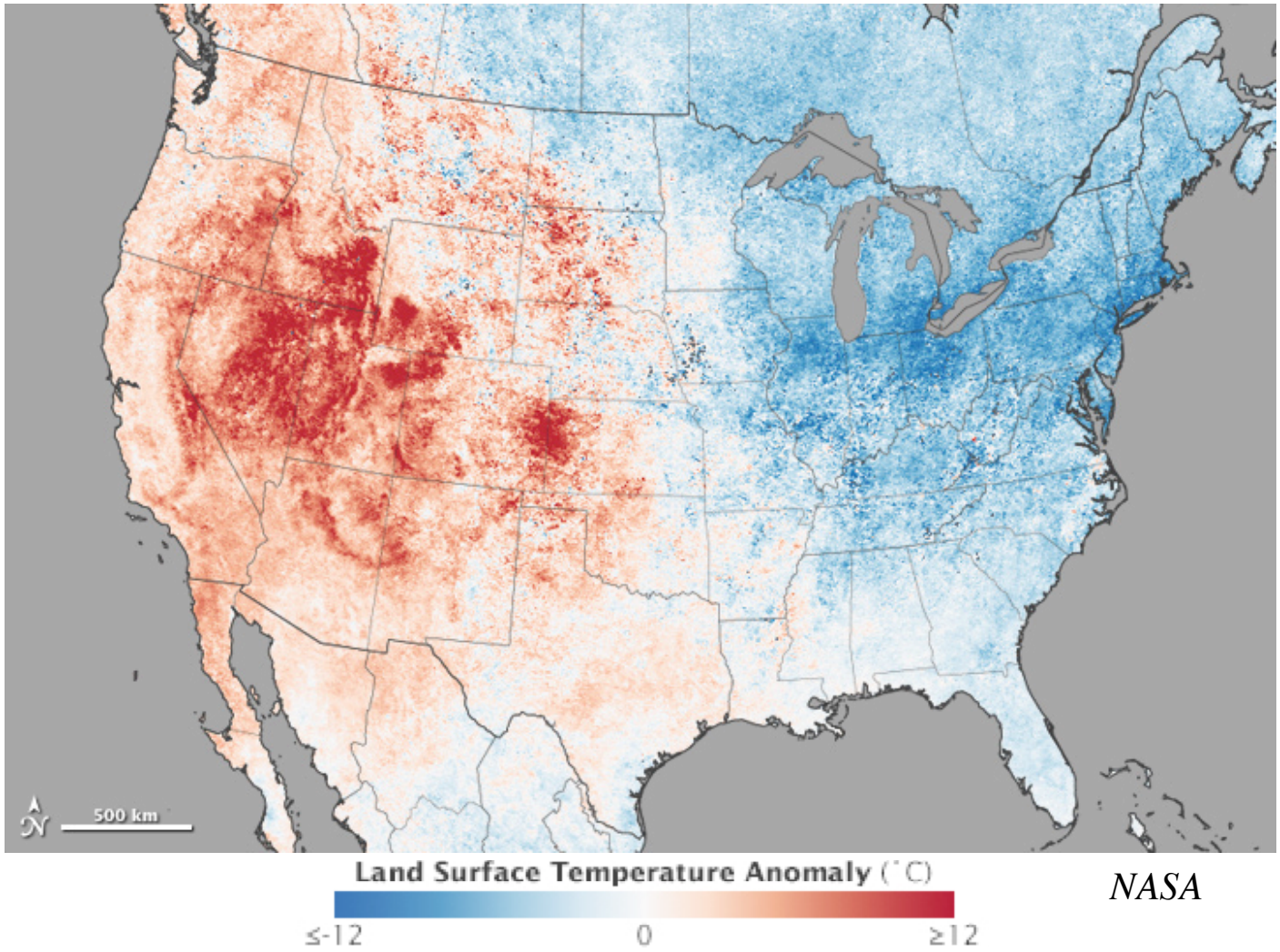


NASA

Yes, February was colder than average!

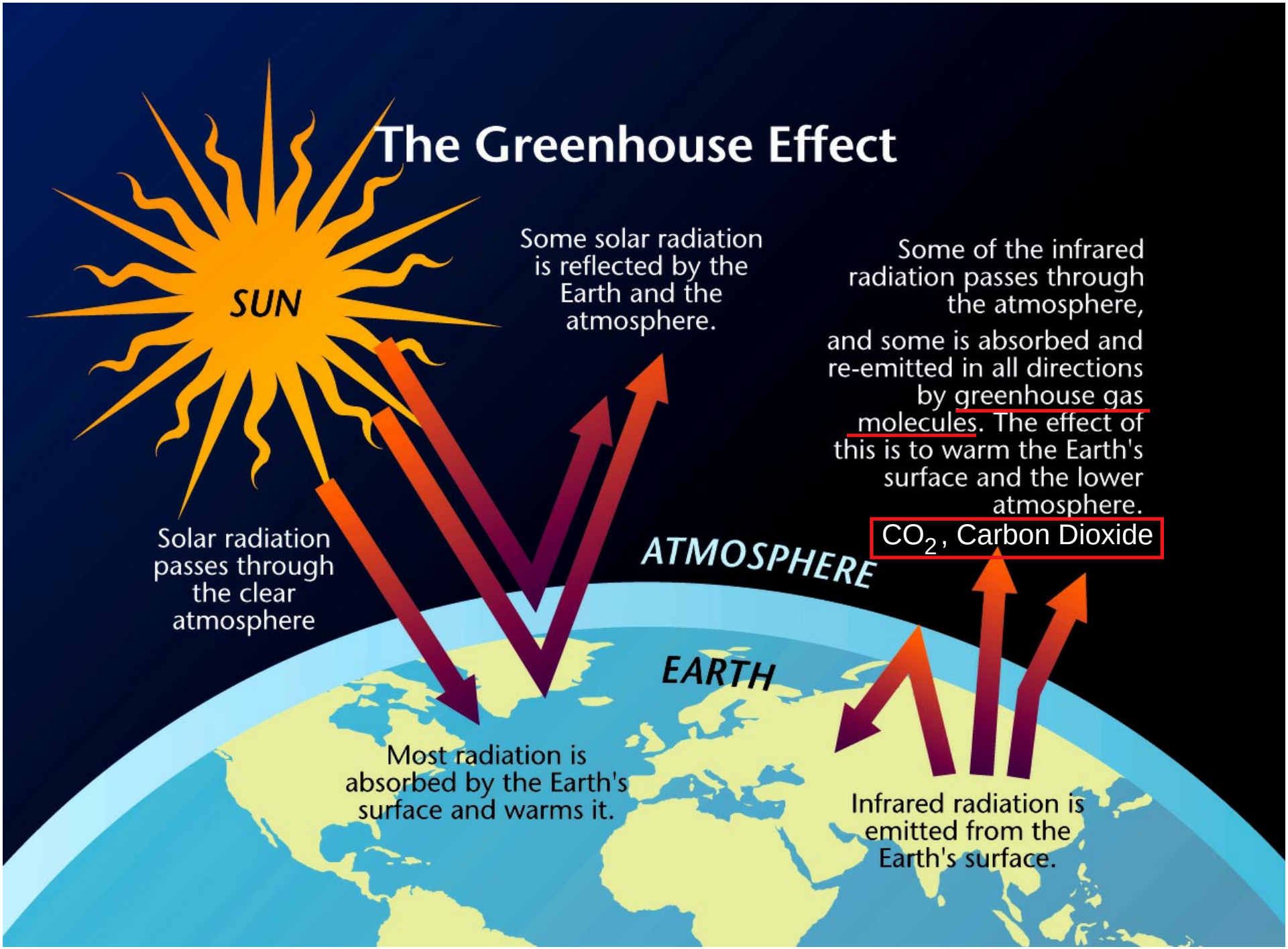
SATELLITE MEASURED TEMPERATURE ANOMALY

Continental U.S., February, 2015

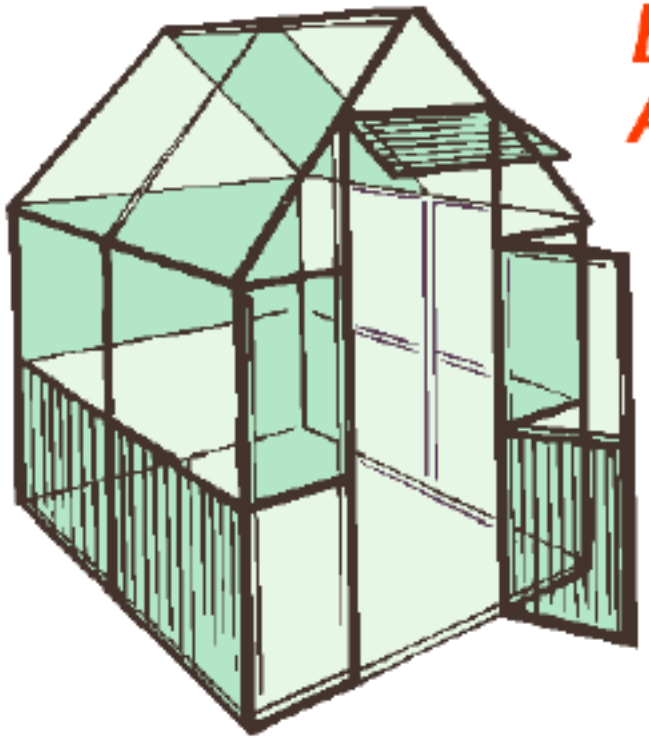


NASA

Don't be misled by local temperatures!


The Greenhouse Effect
SUN
Some solar radiation is reflected by the Earth and the atmosphere.
Some of the infrared radiation passes through the atmosphere,
and some is absorbed and re-emitted in all directions by greenhouse gas molecules. The effect of this is to warm the Earth's surface and the lower atmosphere.
CO_2, Carbon Dioxide
Solar radiation passes through the clear atmosphere
ATMOSPHERE
EARTH
Most radiation is absorbed by the Earth's surface and warms it.
Infrared radiation is emitted from the Earth's surface.

THE GREENHOUSE EFFECT



EARTH'S ENERGY BUDGET: A DELICATE BALANCE

- Sunlight heats the Earth.
- The warm Earth radiates energy (in the form of infrared radiation, or heat) back out to space.
- Some of this infrared radiation is trapped in the atmosphere, giving Earth its temperate climate.

This is the greenhouse effect.

Global average temperature 15°C or 59°F

Without it, the Earth's climate would be like the moon's, harsh and severe.

Global average temperature -19°C or -2 °F

New York Times

Late Edition

Today, cloudy, showers, thunderstorms, high 74. **Tonight,** showers, storms, then clearing, low 55. **Tomorrow,** clouds and sun, breezy, high 69. Weather map, Page C8.

NEW YORK, SATURDAY, MAY 11, 2013

$2.50

Heat-Trapping Gas Passes Milestone, Raising Fears

CO_2 at Level Not Seen in Millions of Years, Portending Major Climate Changes

By JUSTIN GILLIS

The level of the most important heat-trapping gas in the atmosphere, carbon dioxide, has passed a long-feared milestone, scientists reported Friday, reaching a concentration not seen on the earth for millions of years.

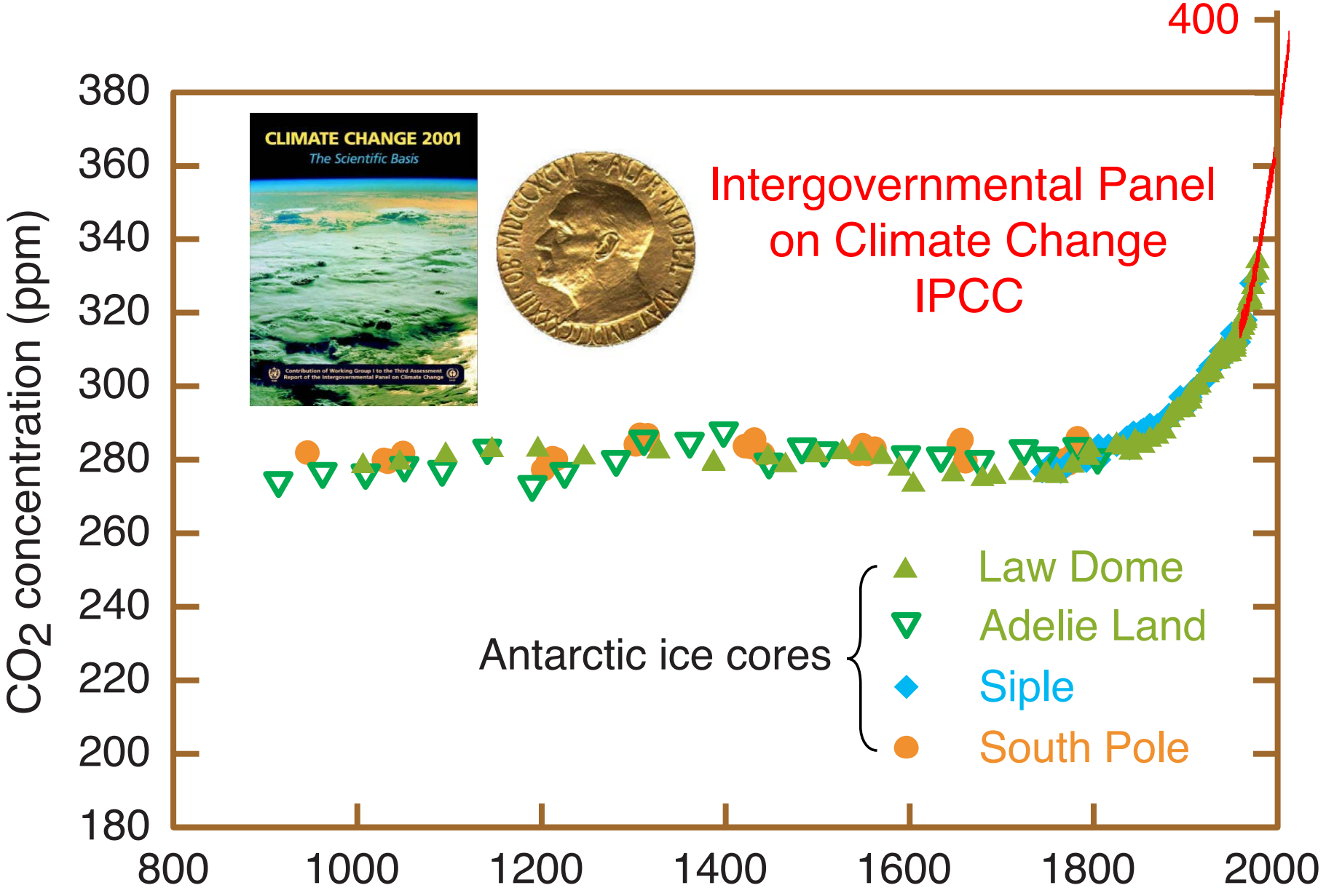
Scientific instruments showed that the gas had reached an average daily level above 400 parts per million — just an odometer moment in one sense, but also a sobering reminder that decades of efforts to bring human-produced emissions under control are faltering.

The best available evidence the high level.

The new measurement came from analyzers atop Mauna Loa, the volcano on the big island of Hawaii that has long been ground zero for monitoring the worldwide trend on carbon dioxide, or CO_2. Devices there sample clean, crisp air that has blown thousands of miles across the Pacific Ocean, producing a record of rising carbon dioxide levels that has been closely tracked for half a century.

Carbon dioxide above 400 parts per million was first seen in the Arctic last year, and had also

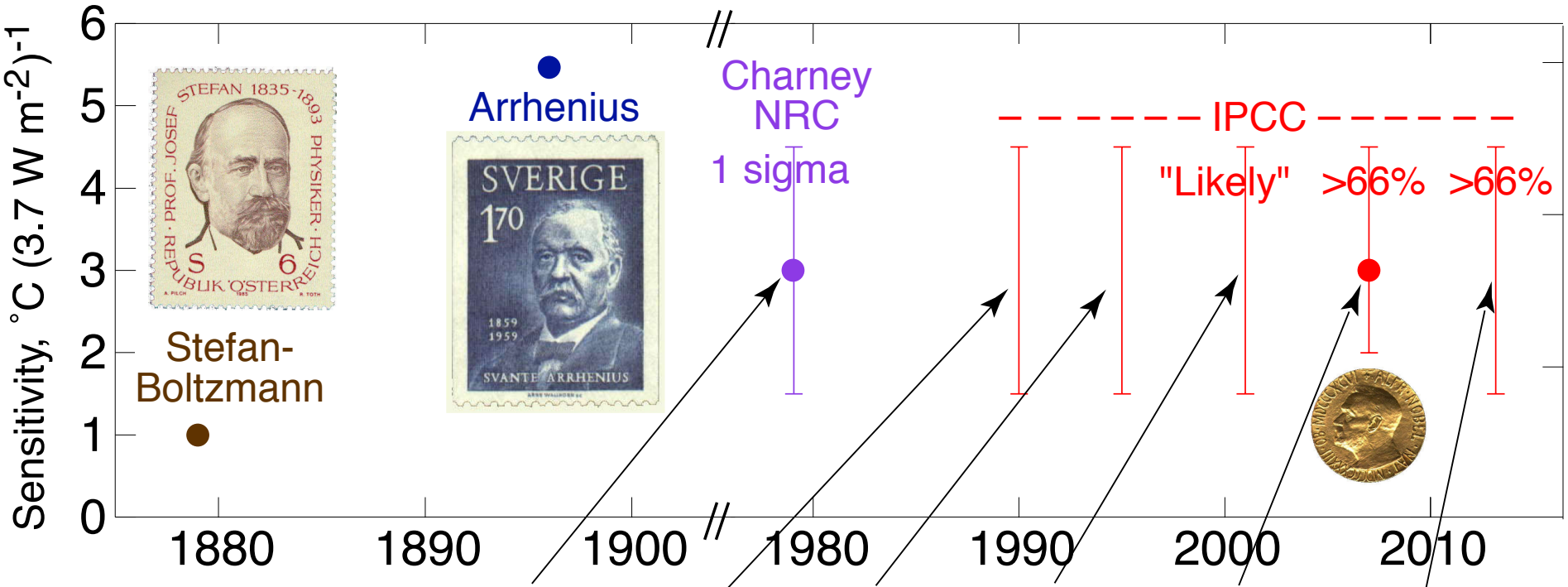
ATMOSPHERIC CARBON DIOXIDE IS INCREASING

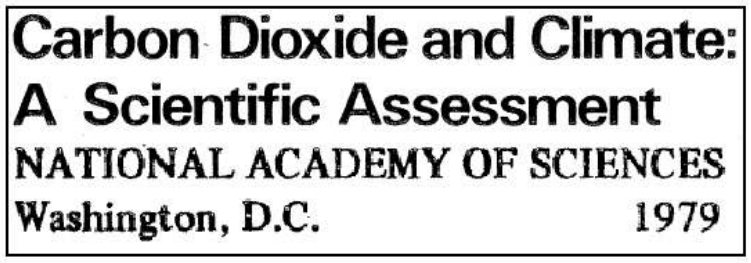


Global carbon dioxide concentration over the last thousand years

CLIMATE SENSITIVITY ESTIMATES THROUGH THE AGES

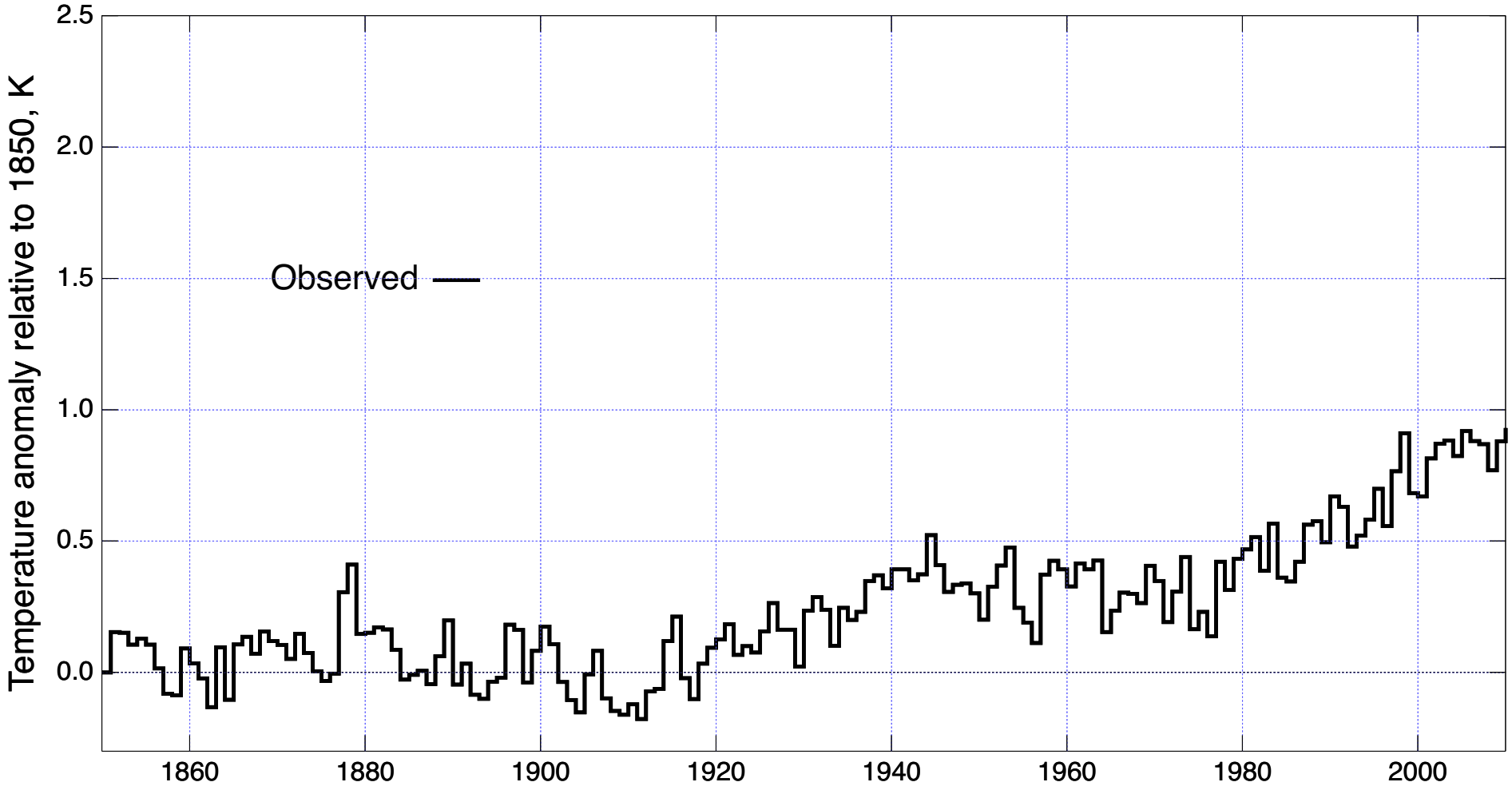
Estimates of central value and uncertainty range from major national and international assessments





Despite extensive research, climate sensitivity remains ***highly uncertain***.

OBSERVED TEMPERATURE CHANGE OVER THE TWENTIETH CENTURY



Observations: Climatic Research Unit, East Anglia, UK

2009 COPENHAGEN ACCORD AGREES ON 2°C MAXIMUM TEMPERATURE RISE

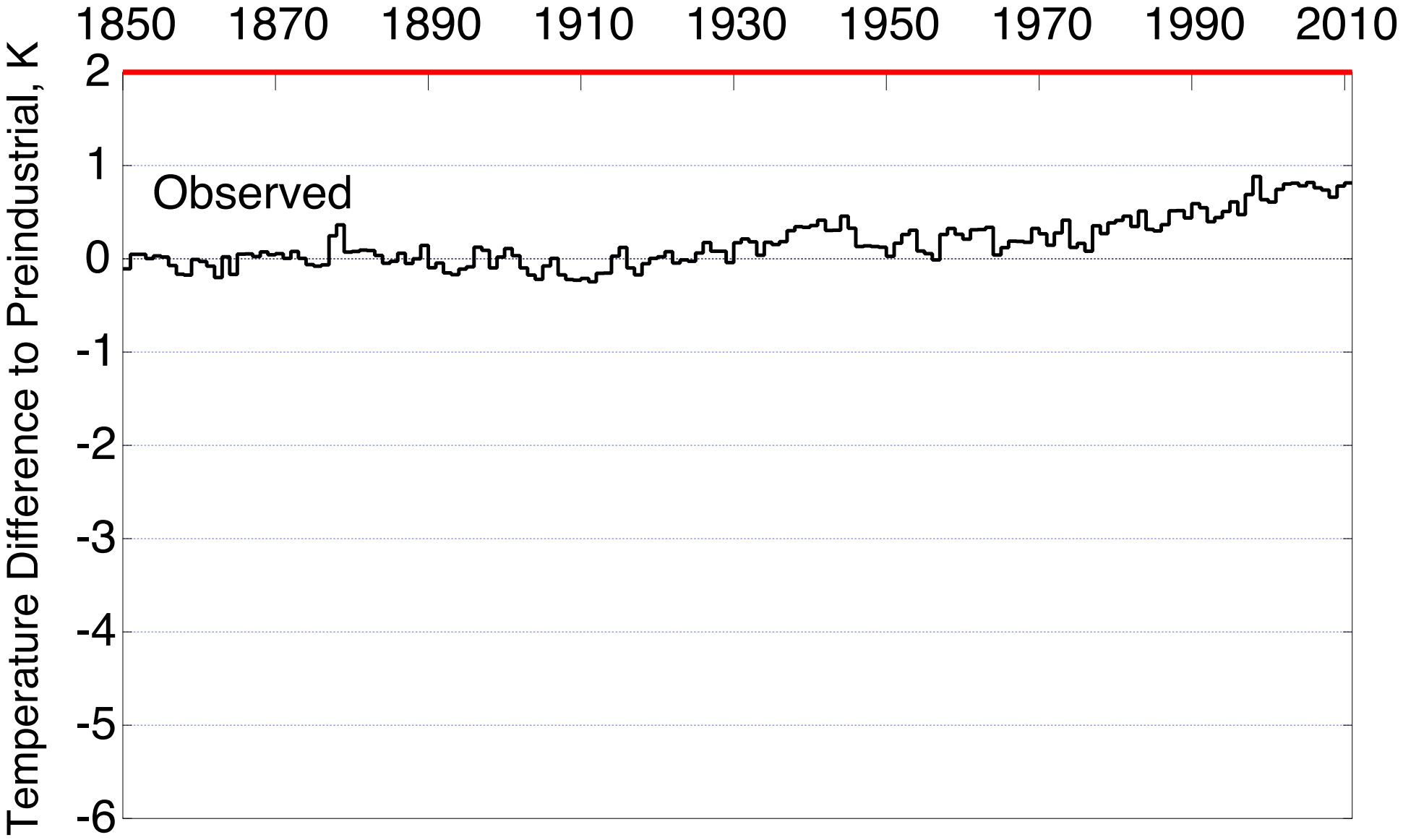
The Heads of State, Heads of Government, Ministers . . . present at the United Nations Climate Change Conference 2009 in Copenhagen:

Albania, Algeria, Armenia, Australia, Austria, . . . [106 countries] . . . , ***United States of America***, Uruguay and Zambia, ***have agreed*** on this Copenhagen Accord. . . .

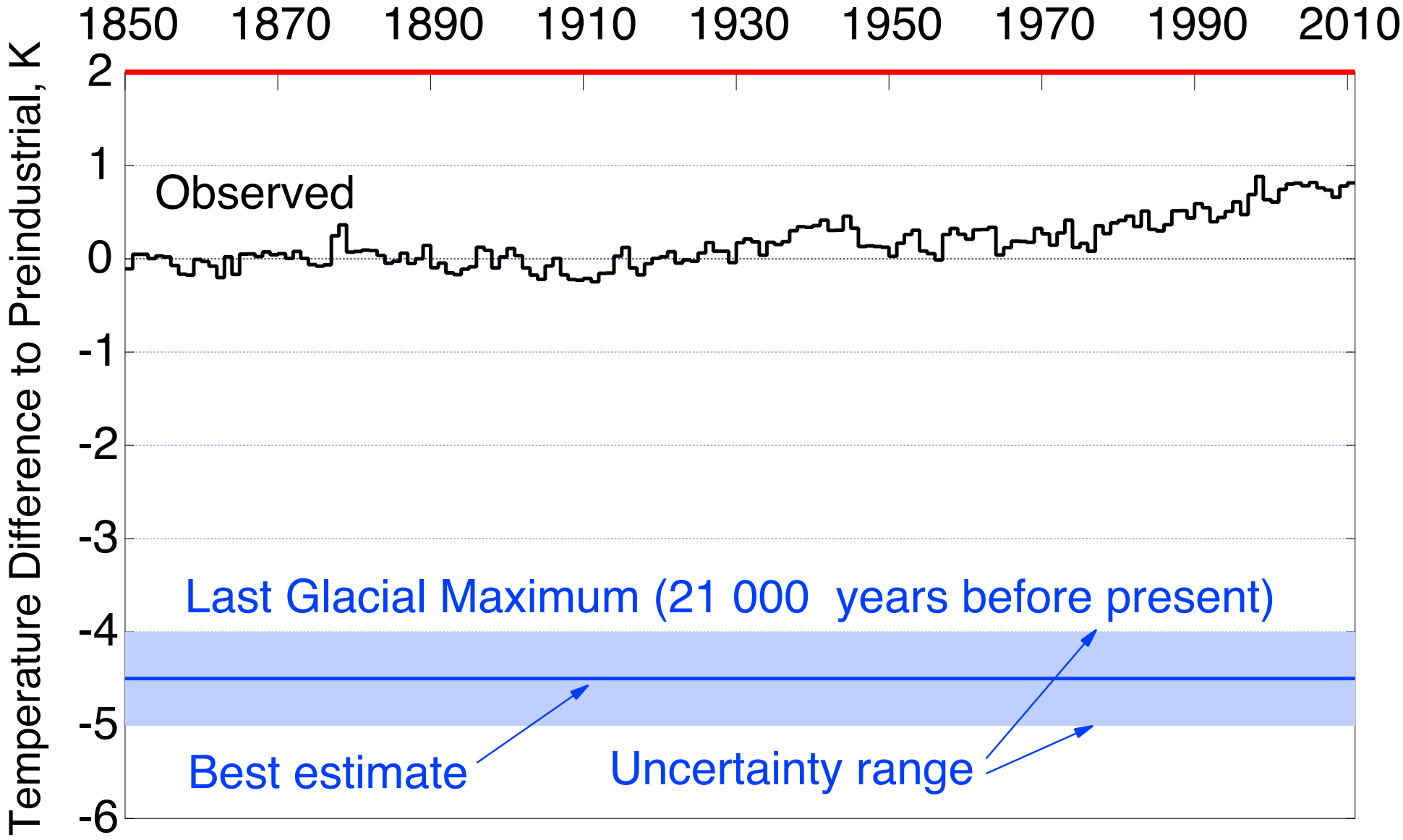
We underline that climate change is one of the greatest challenges of our time. We emphasise our strong political will to urgently combat climate change. . . .

To . . . ***stabilize greenhouse gas concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system***, we shall, ***recognizing the scientific view that the increase in global temperature should be below 2 degrees Celsius*** . . . enhance our long-term cooperative action to combat climate change.

WHY 2 DEGREES?



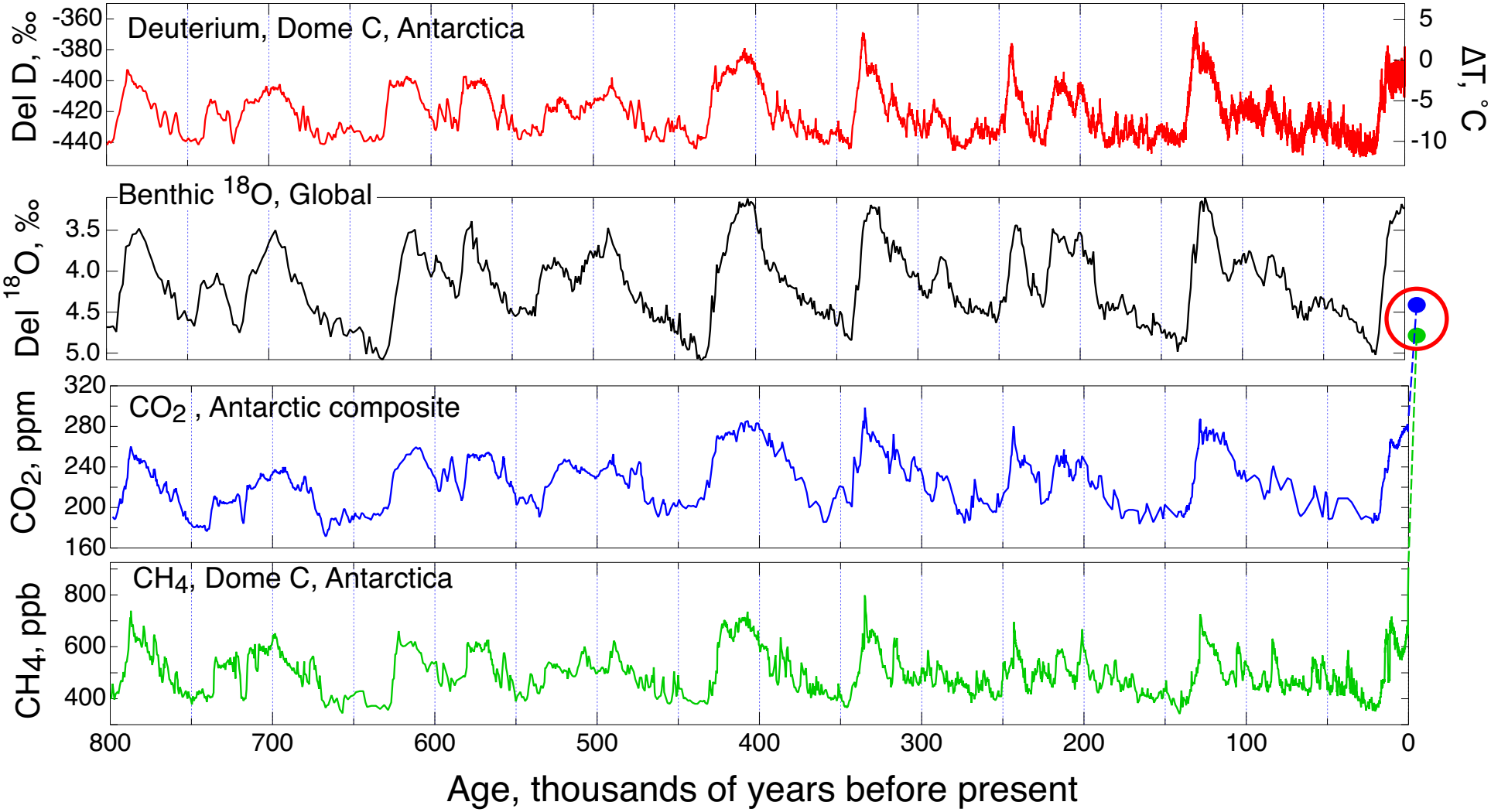
4½ DEGREES OF SEPARATION



2 Degrees is half of an ice age – BUT, in the other direction!

800,000 YEARS OF EARTH'S CLIMATE

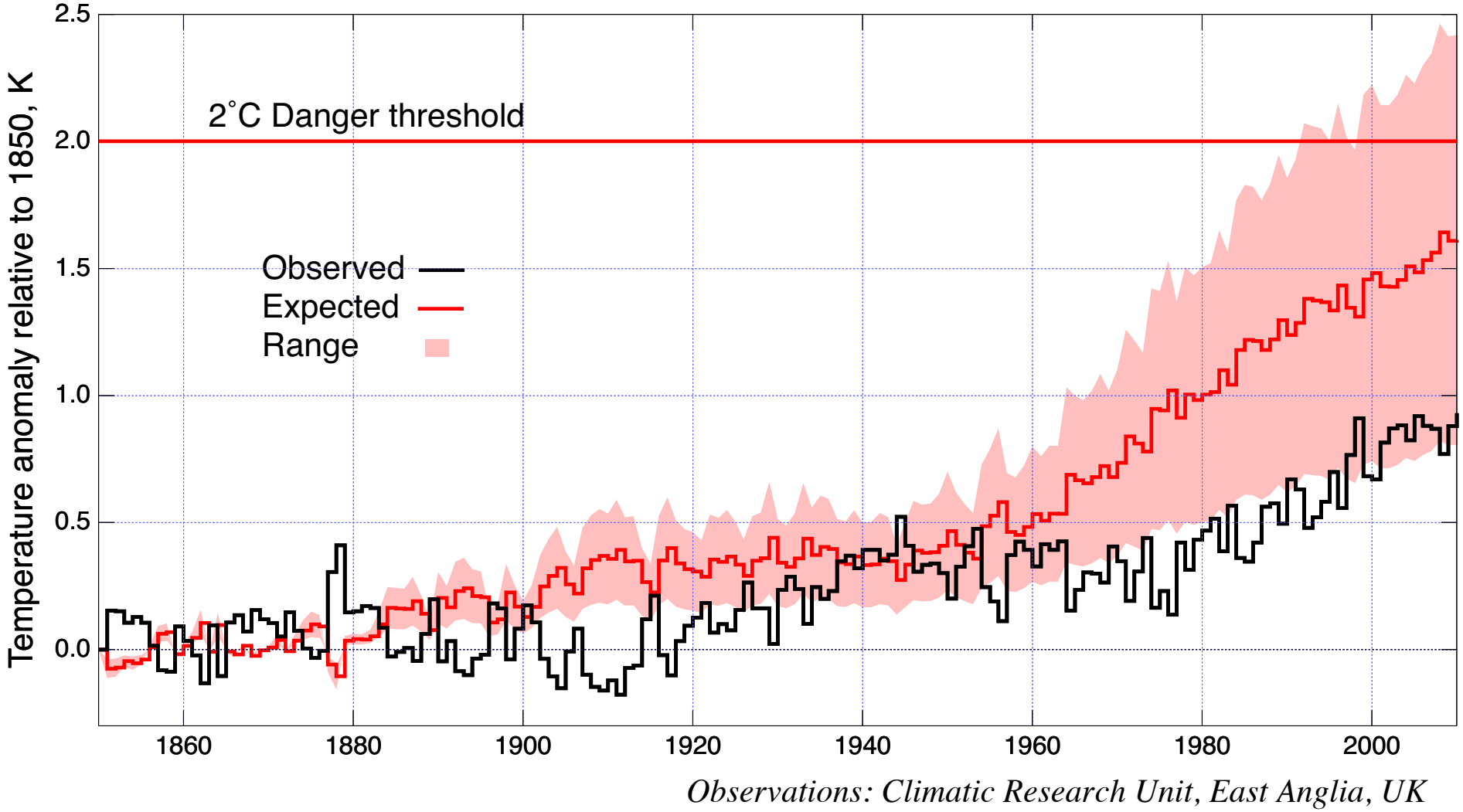
A ***very*** brief time of history



What will the future be? *Que sera, sera*. What will be, will be.

EXPECTED AND OBSERVED TEMPERATURE CHANGE OVER THE TWENTIETH CENTURY

Expected warming for long-lived greenhouse gases only

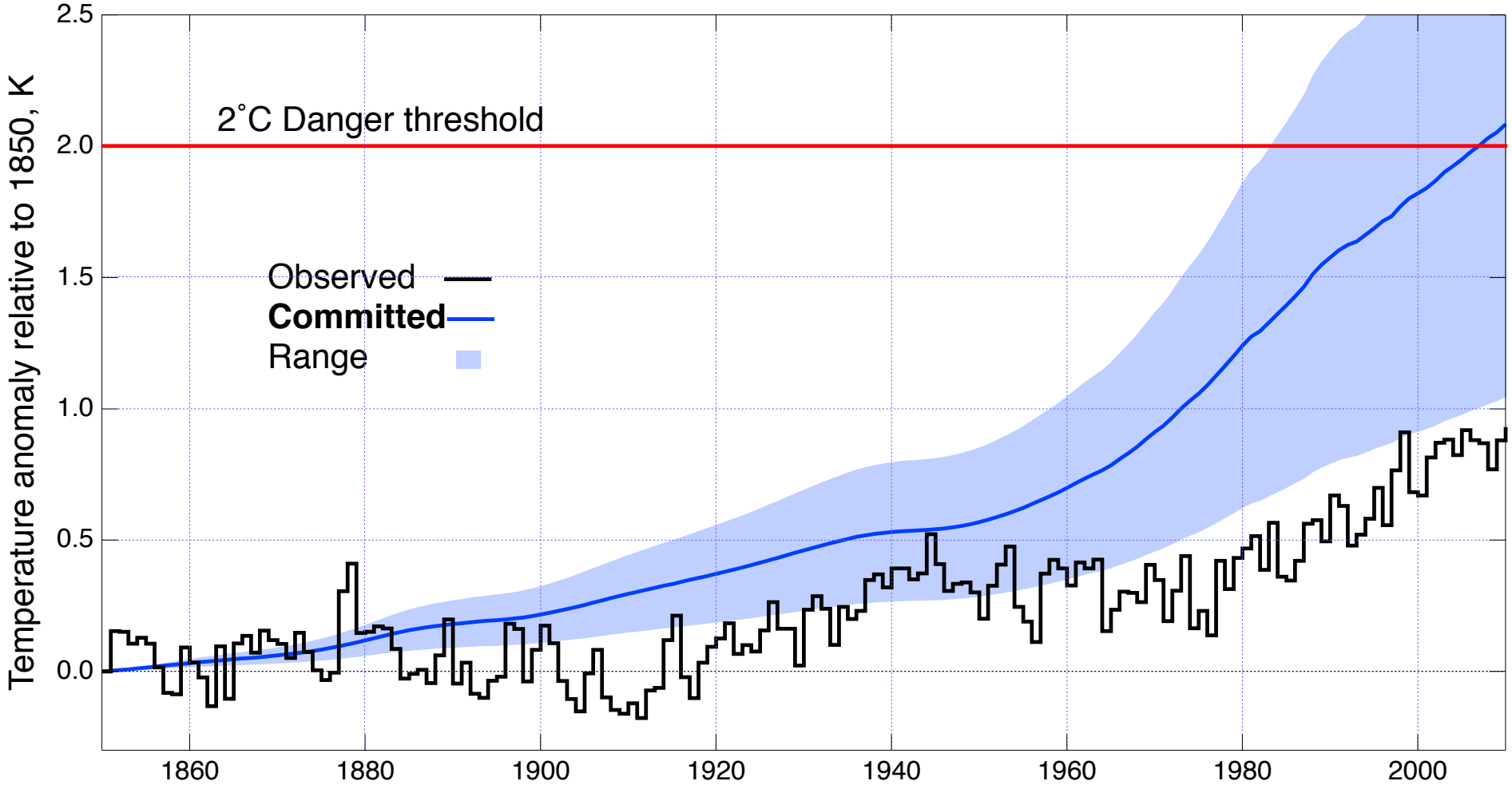


Observations: Climatic Research Unit, East Anglia, UK

Expected increase approaches 2 degree threshold.

COMMITTED AND OBSERVED TEMPERATURE CHANGE OVER THE TWENTIETH CENTURY

Committed warming for long-lived greenhouse gases only



Observations: Climatic Research Unit, East Anglia, UK

Best-estimate committed increase exceeds 2 degree threshold.

WHERE IS ALL THIS CO_2 COMING FROM?

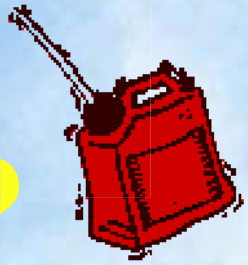
WHO IS RESPONSIBLE?

HOW MUCH CARBON IS IN A GALLON OF GASOLINE?

1 lb?

2 lbs?

3 lbs!?



5 lbs!?!

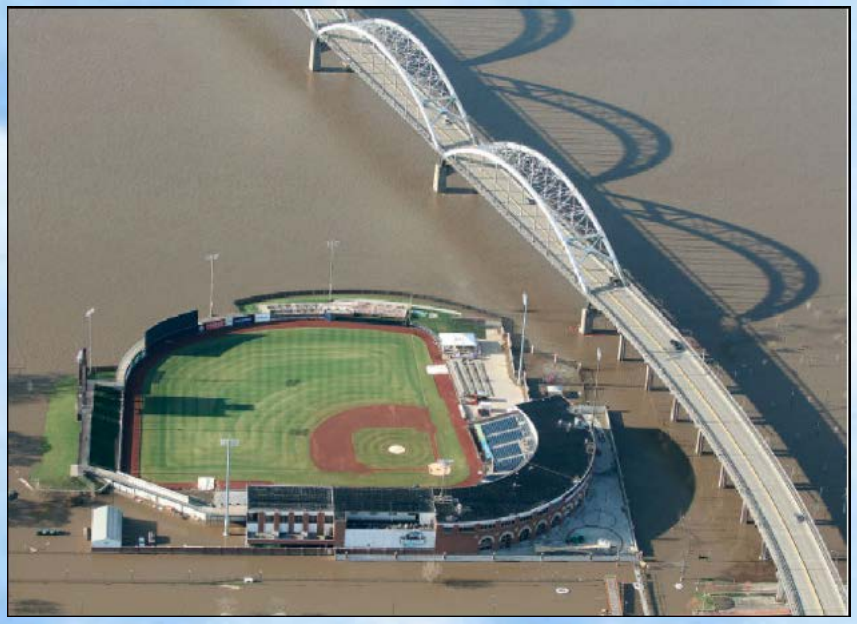
All of this carbon goes into the atmosphere as carbon dioxide when you burn the gasoline in your car.

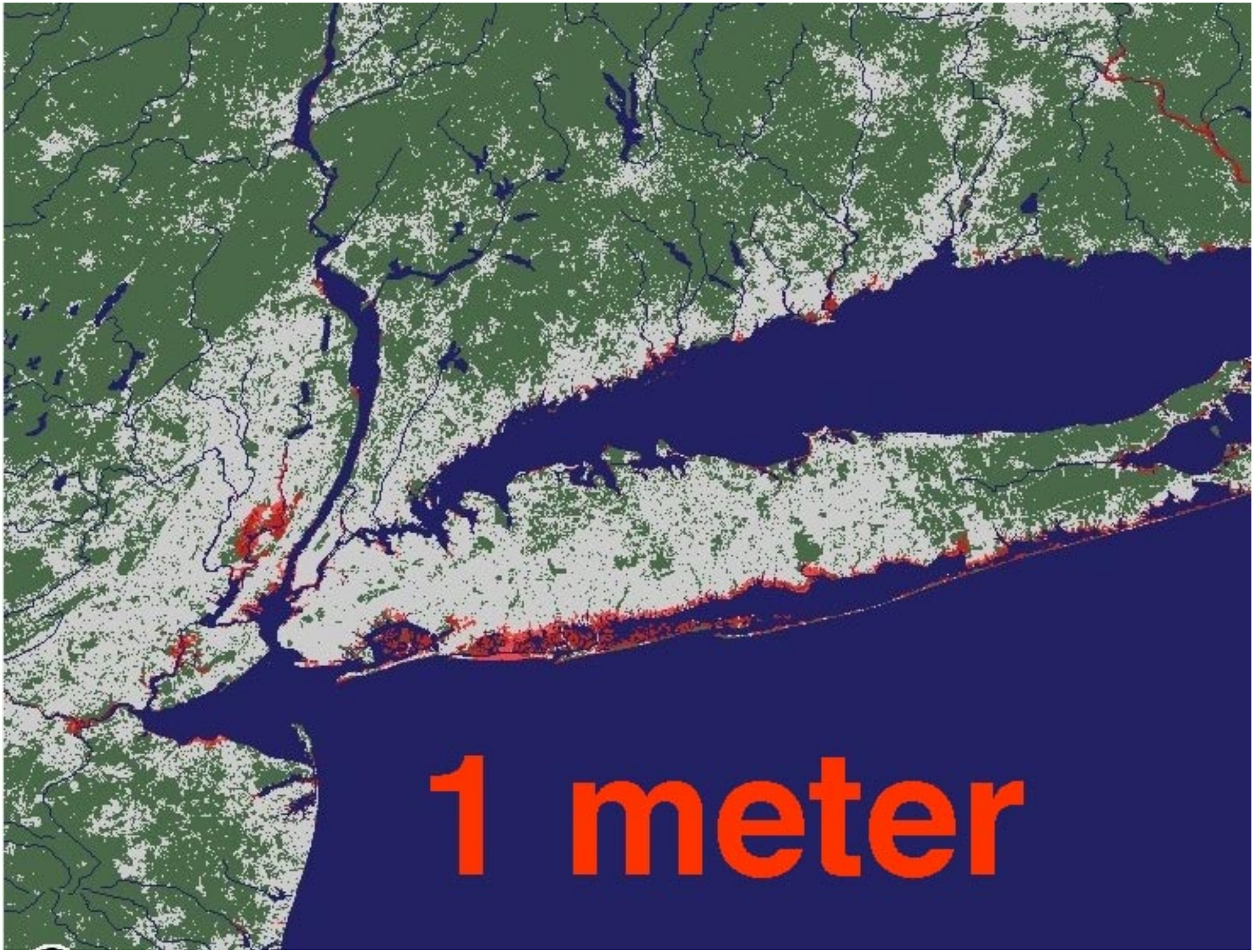
WHAT WILL BE THE FUTURE CLIMATE OF ILLINOIS?

It will be as if you move Illinois 200 miles south.

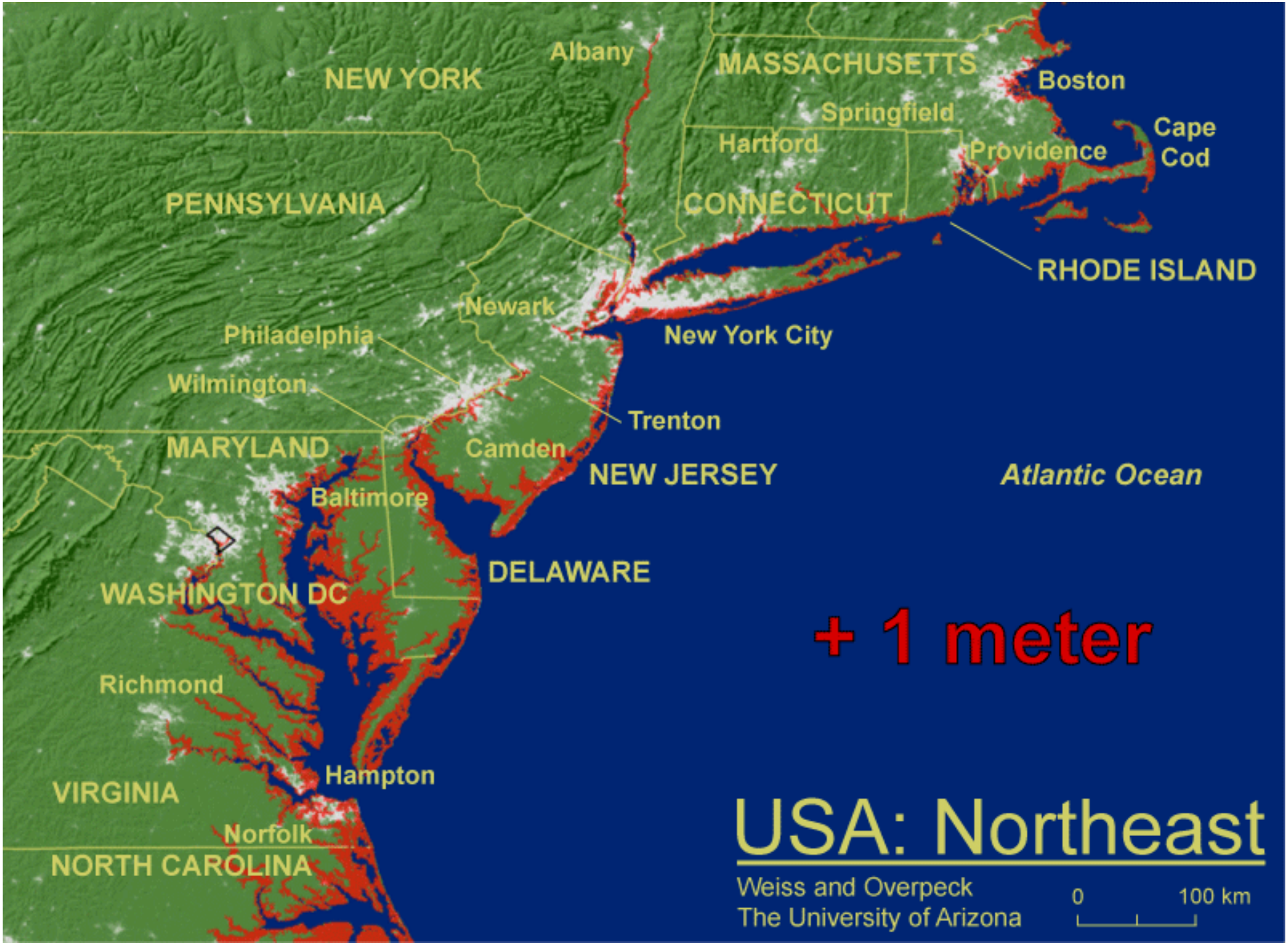
But we don't know if it will be moving to Georgia or the Texas panhandle.

THE NEW NORMAL?




1 meter

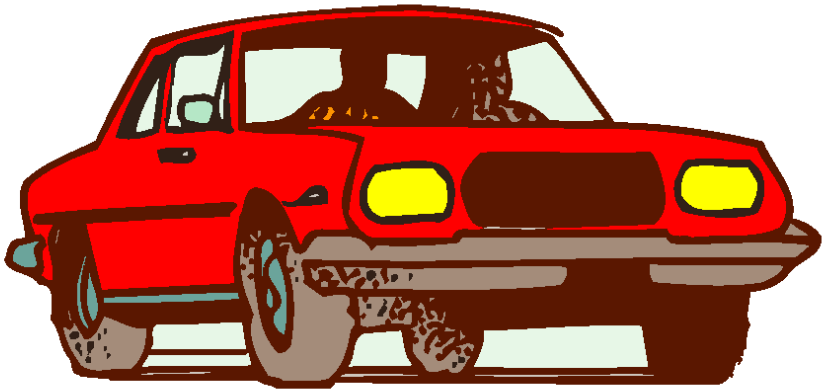
SANDY ON LONG ISLAND – THE NEW NORMAL?


NEW YORK
Albany
MASSACHUSETTS
Boston
Springfield
Hartford
Providence
Cape Cod
PENNSYLVANIA
CONNECTICUT
RHODE ISLAND
Newark
Philadelphia
New York City
Wilmington
Trenton
MARYLAND
Camden
NEW JERSEY
Atlantic Ocean
Baltimore
DELAWARE
WASHINGTON DC
+ 1 meter
Richmond
Hampton
VIRGINIA
Norfolk
NORTH CAROLINA
USA: Northeast
Weiss and Overpeck
The University of Arizona
0
100 km

"Gentlemen, it's time we gave some serious thought to the effects of global warming."

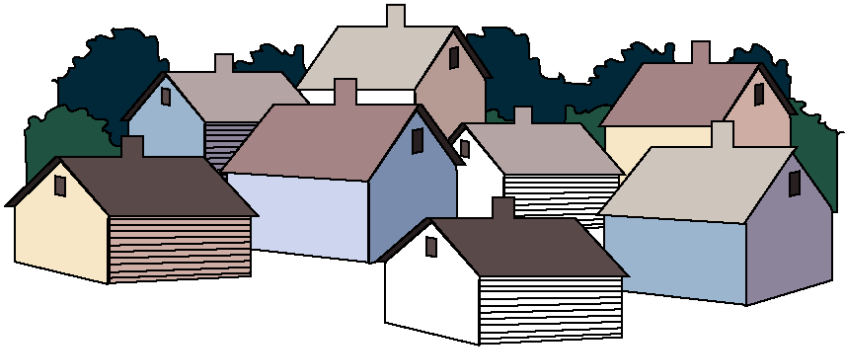
WHERE IS THIS CARBON DIOXIDE COMING FROM?

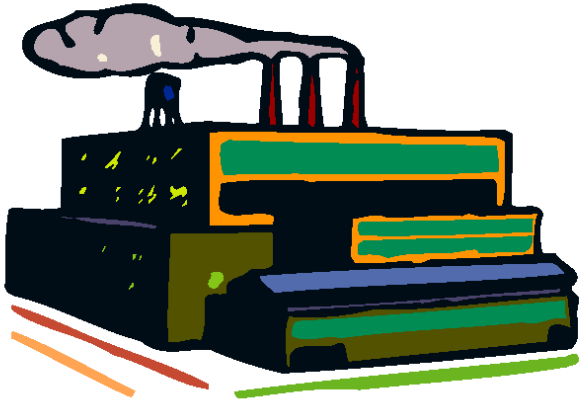
WE ARE ALL RESPONSIBLE.



Burning a gallon of gasoline in your car puts 5 pounds of carbon in the atmosphere as carbon dioxide (CO_2), and it will stay there for decades — maybe a century!

Other sources are home heating and electric power production.





SOLAR PHOTOVOLTAIC ENERGY

Decrease your carbon legacy by generating your own electricity

Decrease your electric bill, too; maybe even to zero!

ENERGY EFFICIENT CARS

Decrease your carbon legacy by driving an energy efficient car

Decrease your gasoline bill, and drive in HOV lane, too!

Global Atmosphere, Global Warming

QUESTIONS ABOUT GLOBAL WARMING

- IS IT REAL?
- IS IT IMPORTANT?
- WHAT IS IT DUE TO?
- HOW MUCH MORE CAN WE EXPECT?
- ARE WE SEEING JUST THE TIP OF THE ICEBERG?

RESEARCH IS HELPING TO ANSWER THESE QUESTIONS.

www.ecd.bnl.gov/steve

THANK YOU

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